Concrete Pavement Design for City Streets

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Concrete Pavement History

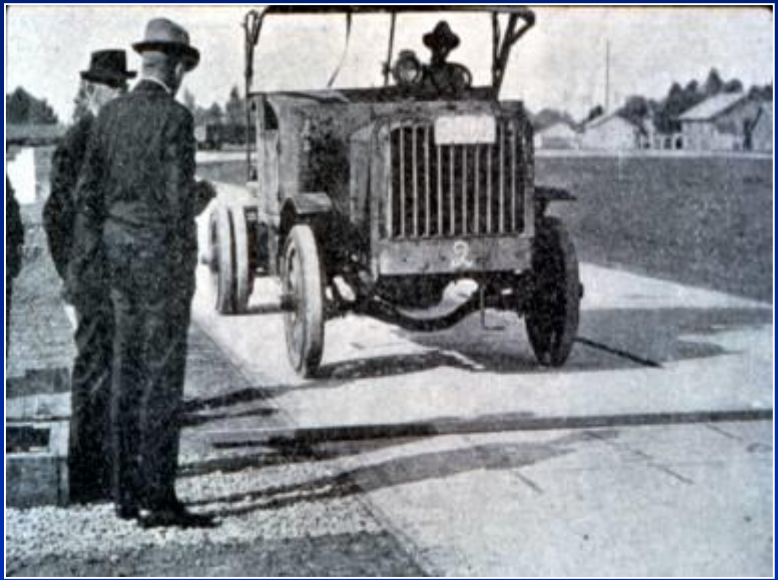
Seedling Miles

- One lane, 9 feet wide
- The industry built these in the hope that once motorists tried it, they would lobby for more miles of paved roads

Old IL 127
North of Greenville

Bates Road Test

- In 1920, Illinois passed a $200 million bond issue to build 9000 miles of paved roads
- To determine the best paving material, they built sections of brick, asphalt, and concrete
- Developed thickness design procedures and chose concrete for the Illinois pavements



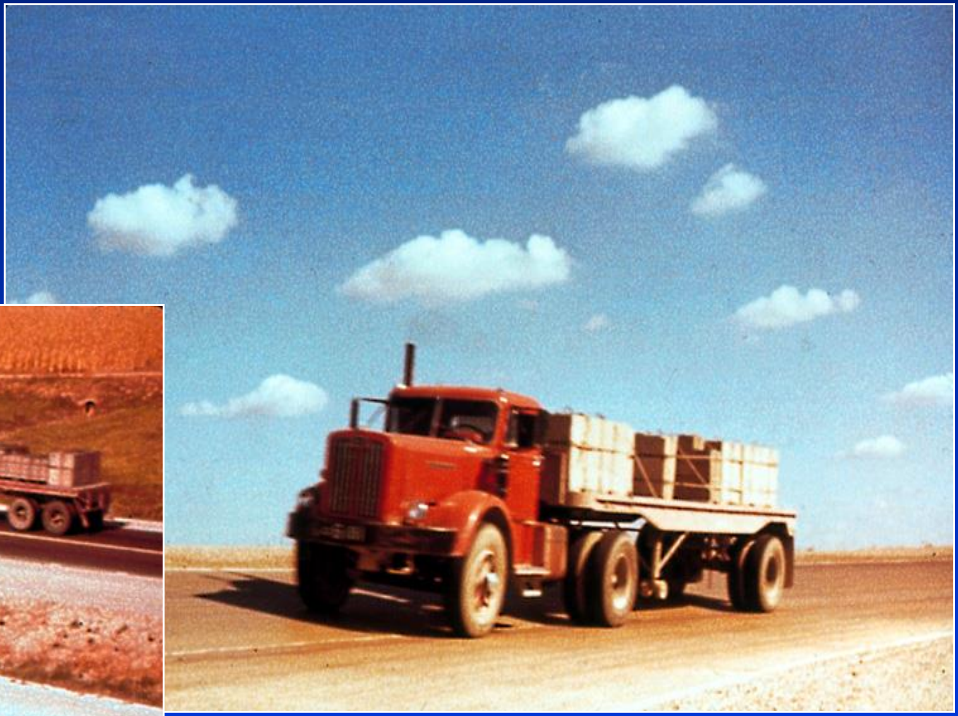
Old WWI Army trucks
with 9000# wheel loads

Source of Much of What We Know About Pavement Design

- President Eisenhower moved us into a new era
- AASHO Road Test
- Late 50’s and early 60’s
- Ottawa, Illinois

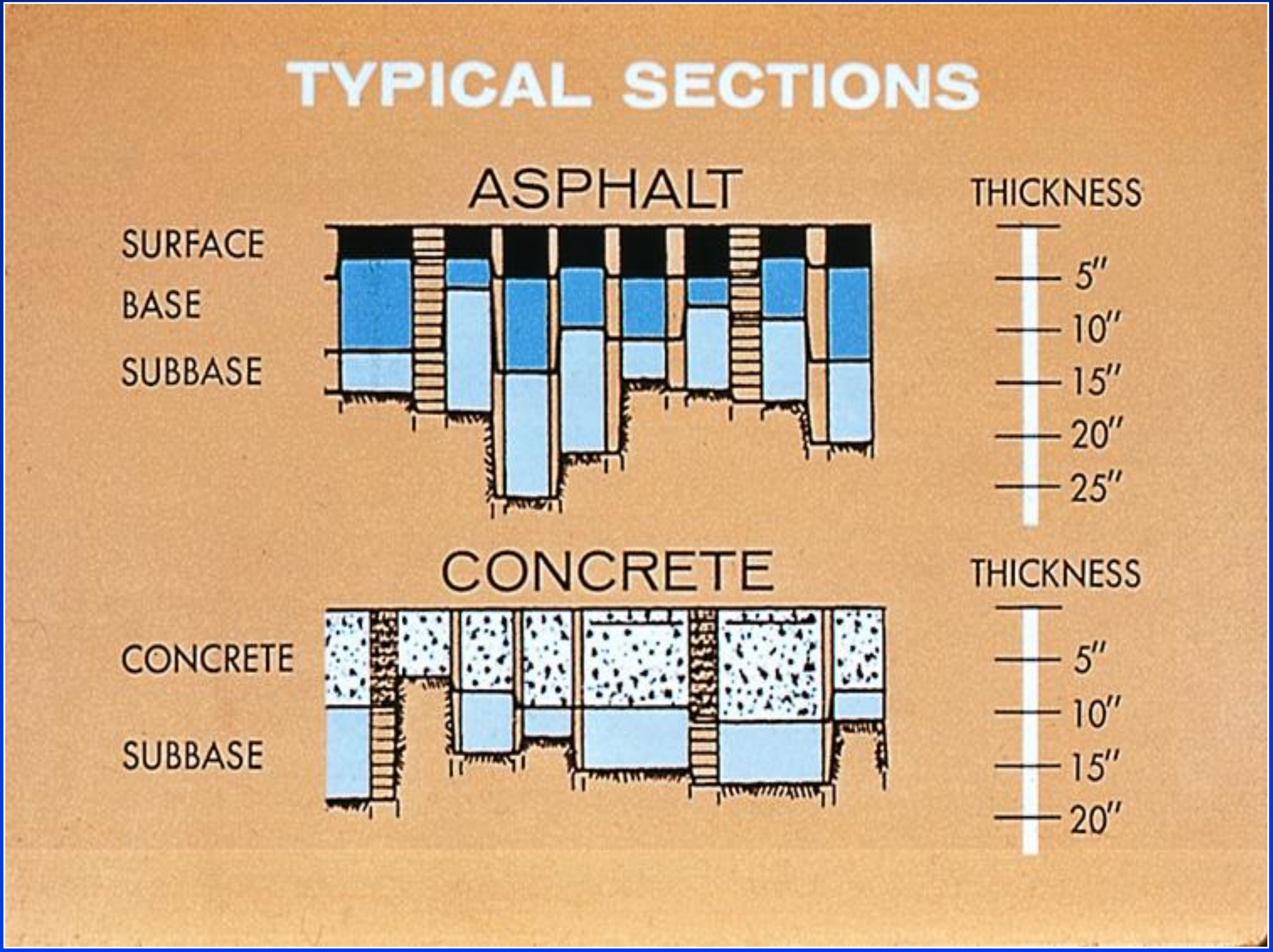
AASHO Test Traffic

Max Single Axle



Max Tandem Axle

Typical AASHO Pavement Sections

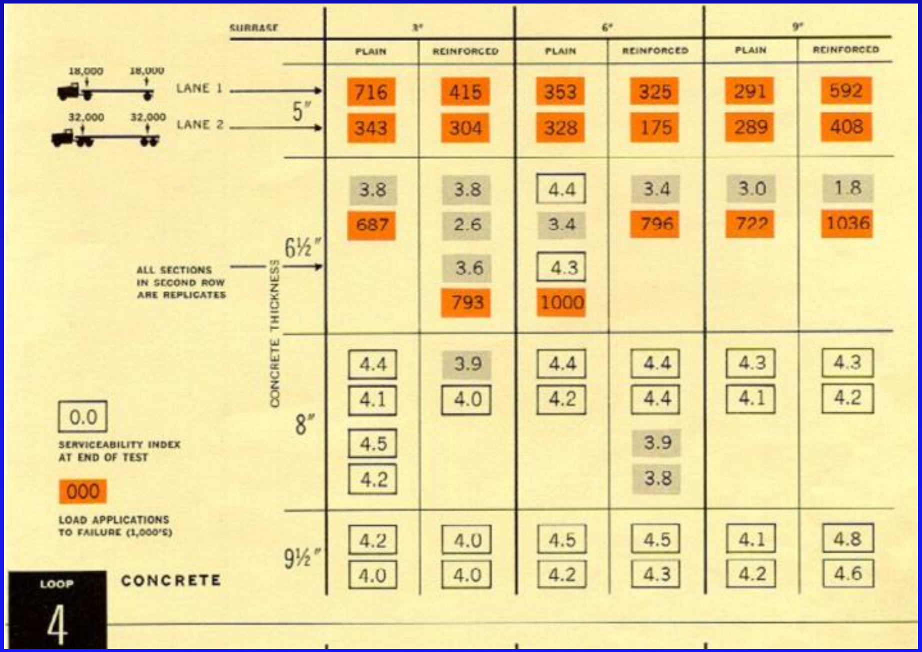


Keys to Quality Design
(Some things never change)

- The platform matters
  - Stable
  - Uniform
  - Not necessarily strong

Keys to Quality Design
(Some things never change)

- The platform matters
- Thickness & traffic matter



AASHO Road Test Results

18,000 18,000 LANE 1

32,000 32,000 LANE 2

CONCRETE THICKNESS	SUBBASE 3" PLAIN	3" REINFORCED	6" PLAIN	6" REINFORCED	9" PLAIN	9" REINFORCED
5" (Lane 1)	716	415	353	325	291	592
5" (Lane 2)	343	304	328	175	289	408
6½"	3.8	3.8	4.4	3.4	3.0	1.8
6½"	687	2.6	3.4	796	722	1036
6½"		3.6	4.3			
6½"		793	1000			
8"	4.4	3.9	4.4	4.4	4.3	4.3
8"	4.1	4.0	4.2	4.4	4.1	4.2
8"	4.5			3.9		
8"	4.2			3.8		
9½"	4.2	4.0	4.5	4.5	4.1	4.8
9½"	4.0	4.0	4.2	4.3	4.2	4.6

ALL SECTIONS IN SECOND ROW ARE REPLICATES

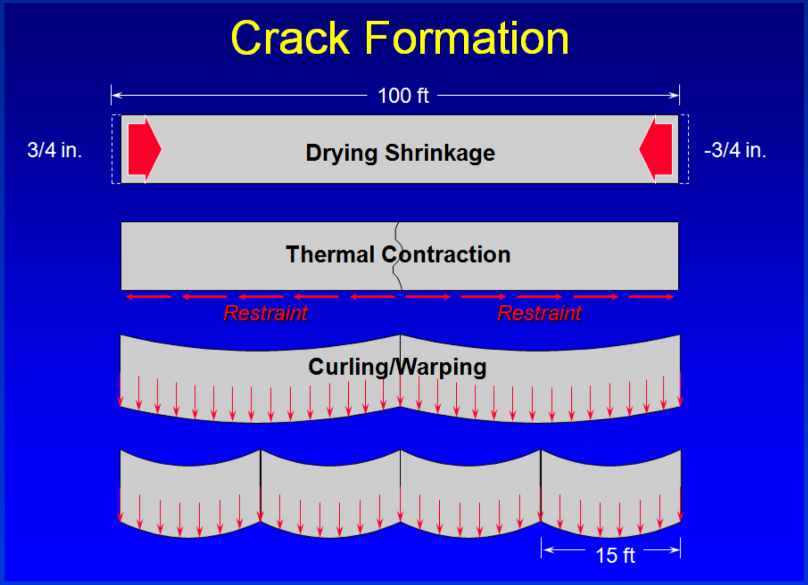
0.0 SERVICEABILITY INDEX AT END OF TEST

000 LOAD APPLICATIONS TO FAILURE (1,000'S)

LOOP 4 CONCRETE

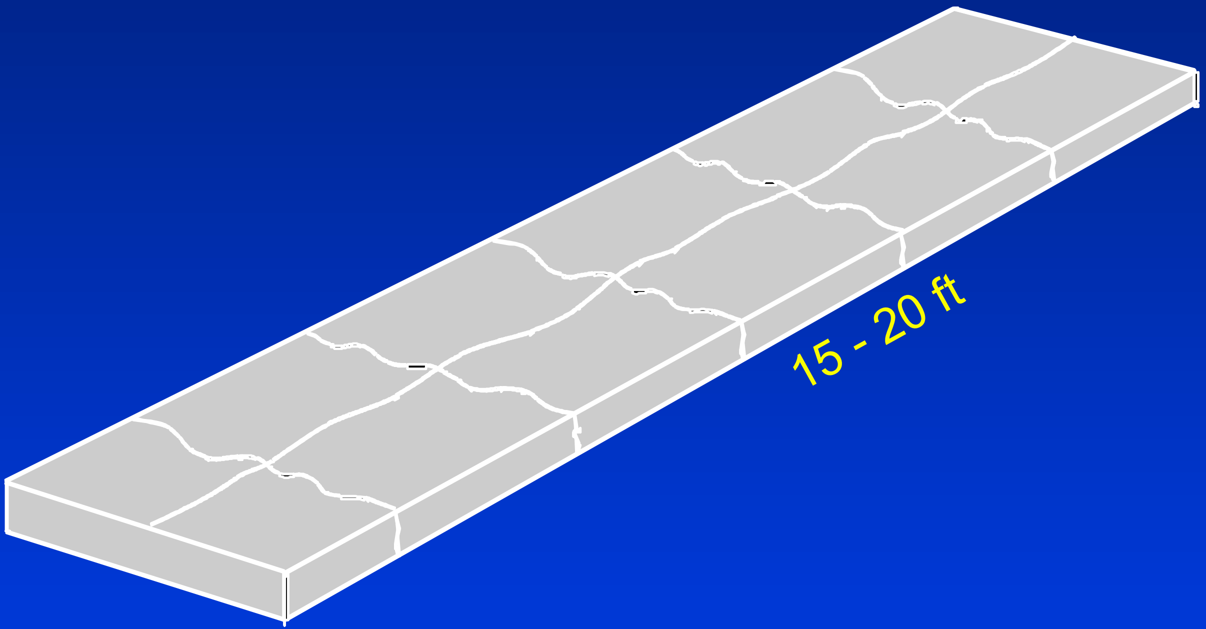
Keys to Quality Design
(Some things never change)

- The platform matters
- Thickness & traffic matter
- Concrete cracks, so lets deal with it



Natural Crack Development

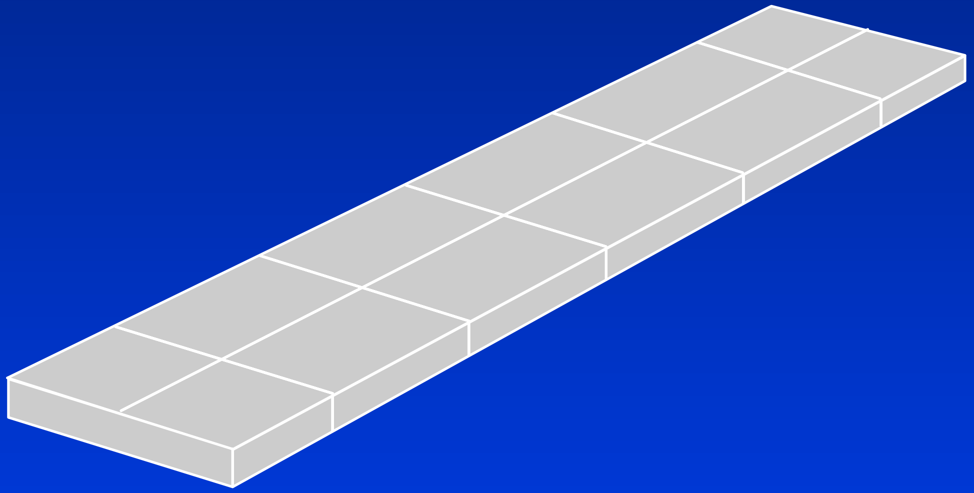
- Temperature Gradients
- Moisture Gradients
- Thermal Cycles
- Loading



Usually starts sometime after 12 hours and may take months

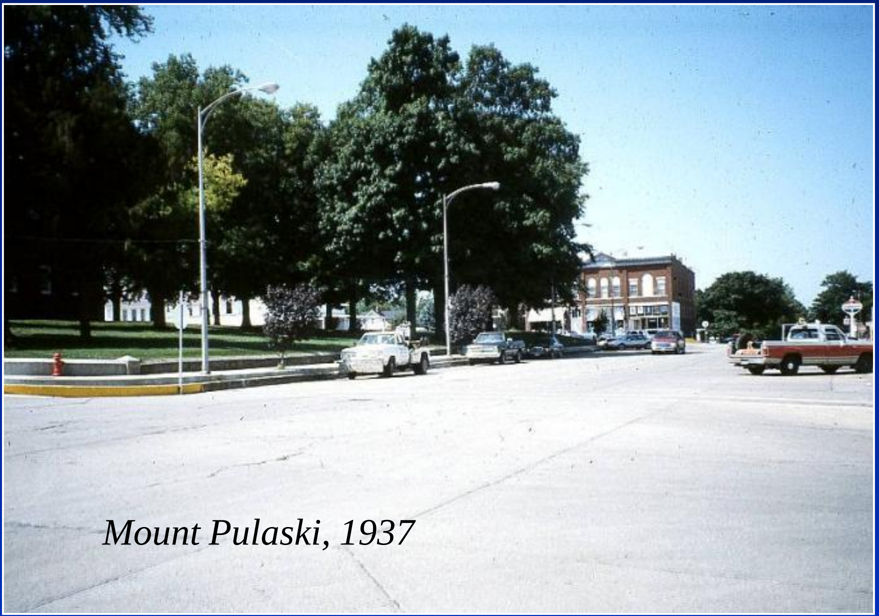
Natural Crack Development

- Proper jointing early provides a series of saw cuts (joints) spaced to control crack formation
- No such thing as too many joints!



Do it Right and Concrete Pavements Provide…

- Longevity
- Low annual cost

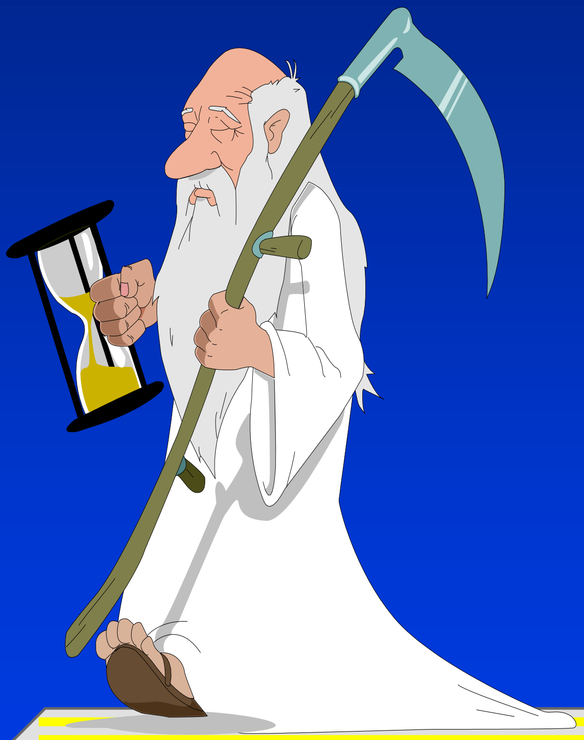


Mount Pulaski, 1937

Urbana, 1919

Not too far from here, 1914

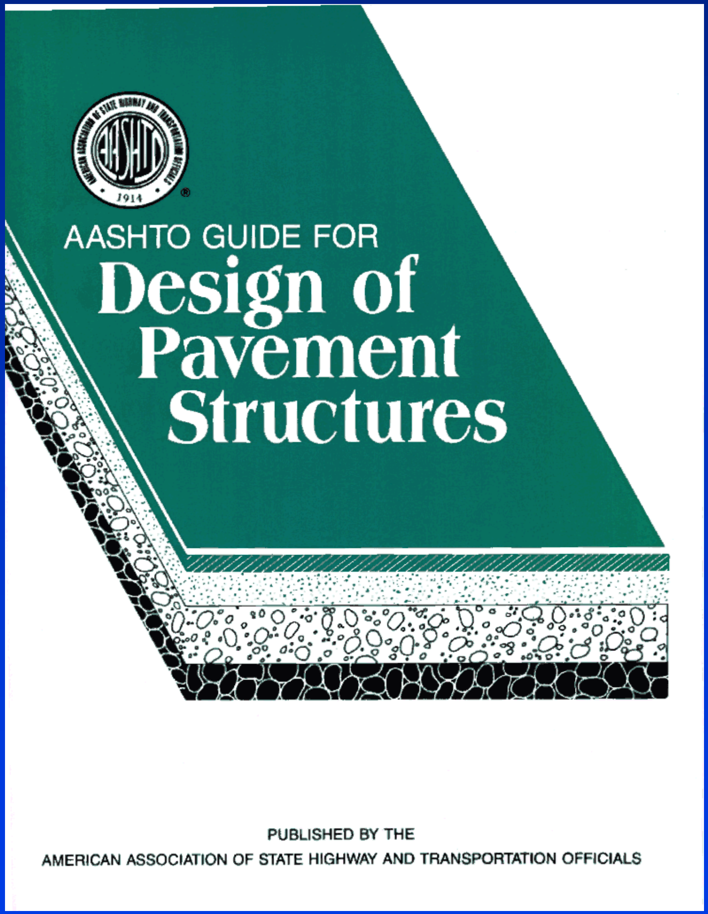
Concrete Has Stood the Test of Time in Illinois



- Concrete on IL Interstate system has carried from 1.6 to 7.8 times its design traffic
- Hundreds of blocks of concrete city streets are in excess of 50 years old
- Some streets are over 90 years old

All were designed with a 20-year life!!!

AASHTO
’93 Guide



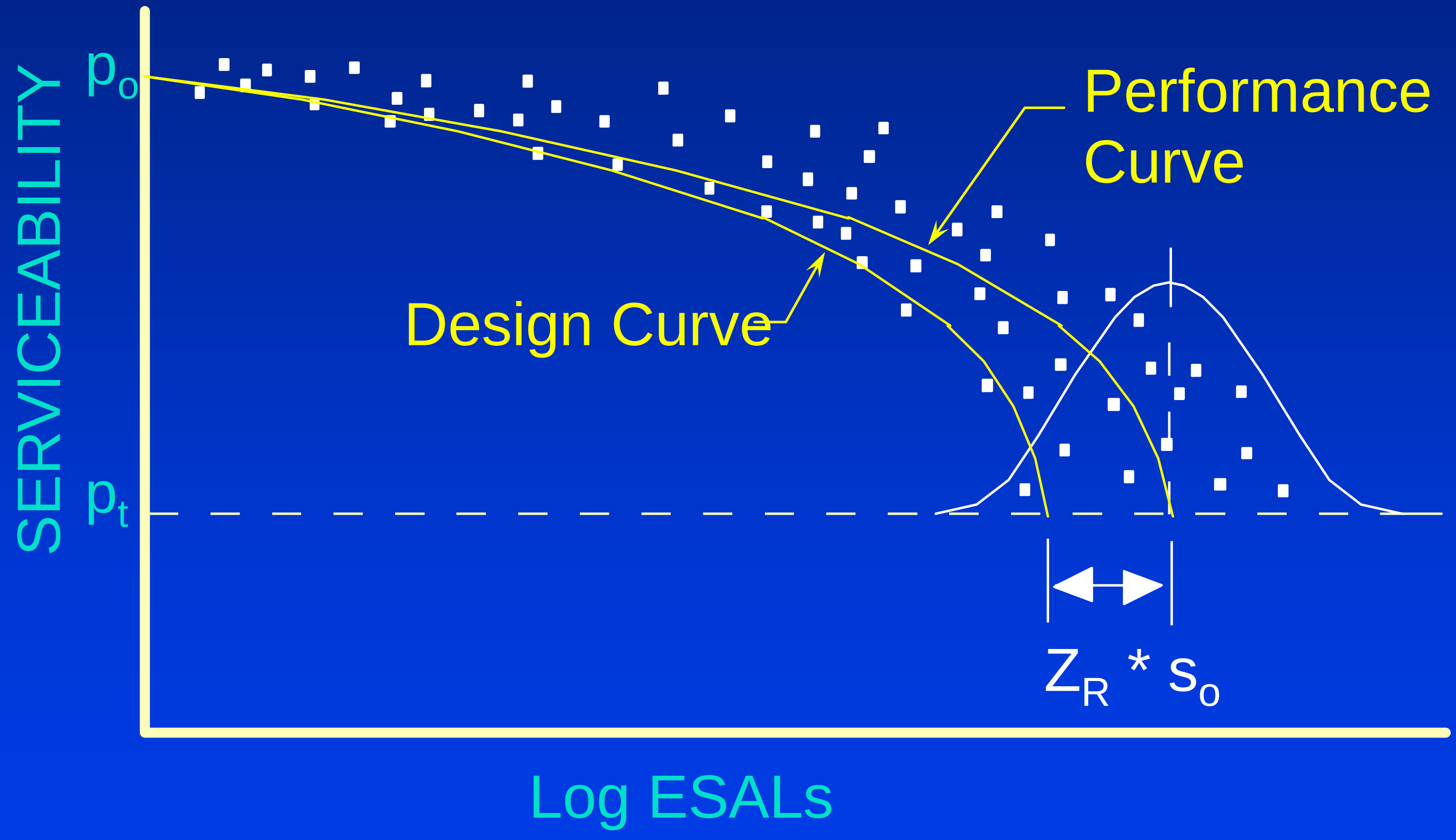
- Pavements Can be Compared at Roughly Equivalent Levels of Reliability
- Principles in both versions are identical for new construction

Reliability

What is it?

- Probability of “Winning”
- Factor of Safety
- Usually Expressed as %

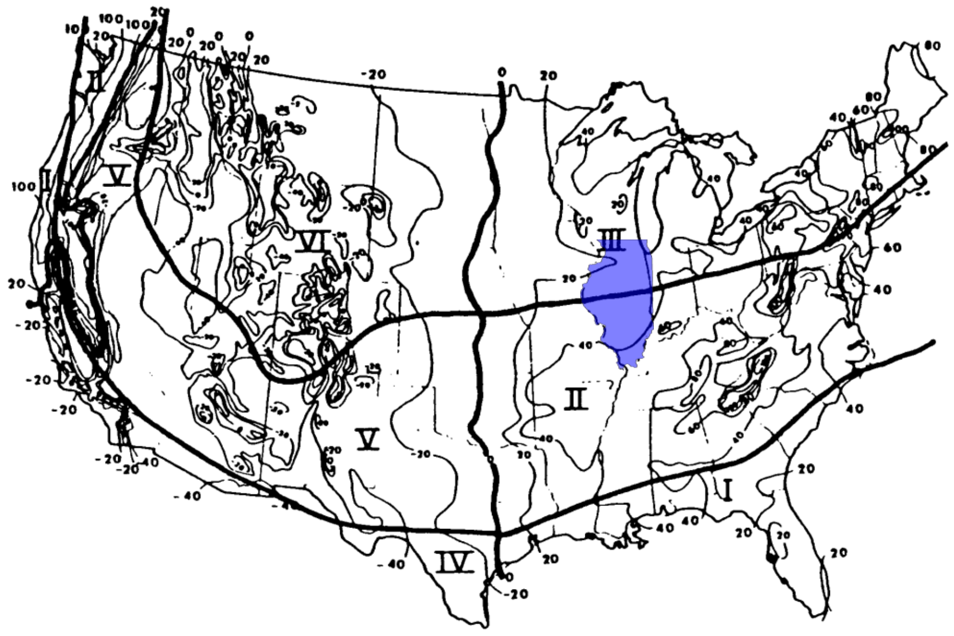
AASHTO DESIGN
Reliability



AASHTO '93 for Local Roads

Climatic Zones

For
Flexible Pavements



REGION	CHARACTERISTICS
I	Wet, no freeze
II	Wet, freeze – thaw cycling
III	Wet, hard-freeze, spring thaw
IV	Dry, no freeze
V	Dry, freeze – thaw cycling
VI	Dry, hard freeze, spring thaw

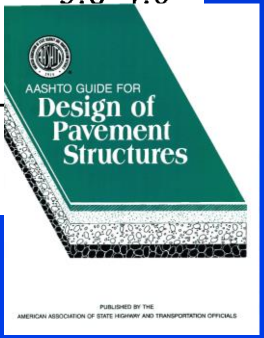
Figure 4.1. The Six Climatic Regions in the United States (*12*)

AASHTO '93 Local Roads Catalog Designs

Table 4.7. Flexible Pavement Design Catalog for Low-Volume Roads: Recommended Ranges of Structural Number (SN) for Six U.S. Climatic Regions, Three Levels of Axle Load Traffic and Five Levels of Roadbed Soil Quality— Inherent Reliability: 75 percent

Relative Quality of Roadbed Soil	Traffic Level	U.S. Climatic Region					
		I	II	III	IV	V	VI
Very good	High	2.6–2.7*	2.8–2.9	3.0–3.2	2.4–2.5	2.7–2.8	3.0–3.2
	Medium	2.3–2.5	2.5–2.7	2.7–3.0	2.1–2.3	2.4–2.6	2.7–3.0
	Low	1.6–2.1	1.8–2.3	2.0–2.6	1.5–2.0	1.7–2.2	2.0–2.6
Good	High	2.9–3.0	3.0–3.2	3.3–3.4	2.7–2.8	3.0–3.1	3.3–3.4
	Medium	2.6–2.8	2.7–3.0	3.0–3.2	2.4–2.6	2.6–2.9	2.9–3.2
	Low	1.9–2.4	2.0–2.6	2.2–2.8	1.8–2.3	2.0–2.5	2.2–2.8
Fair	High	3.2–3.3	3.3–3.4	3.4–3.5	3.0–3.2	3.2–3.3	3.4–3.5
	Medium	2.8–3.1	2.9–3.2	2.7–3.3	2.7–3.0	2.8–3.1	3.0–3.3
	Low	2.1–2.7	2.2–2.8	2.3–2.9	2.0–2.6	2.1–2.7	2.3–2.9
Poor	High	3.5–3.6	3.6–3.7	3.7–3.9	3.4–3.5	3.5–3.6	3.7–3.8
	Medium	3.1–3.4	3.2–3.5	3.4–3.6	3.0–3.3	3.1–3.4	3.3–3.6
	Low	2.4–3.0	2.4–3.0	2.5–3.2	2.3–2.8	2.3–2.9	2.5–3.2
Very poor	High	3.8–3.9	3.8–4.0	3.8–4.0	3.6–3.8	3.7–3.8	3.8–4.0
	Medium	3.4–3.7	3.5–3.8	3.5–3.7	3.3–3.6	3.3–3.6	[illegible]
	Low	2.6–3.2	2.5–3.3	2.6–3.3	2.5–3.1	2.5–3.1	[illegible]

*Recommended range of structural number (SN).



AASHTO '93 Local Roads Catalog Designs

Table 4.9(b). Rigid Design Catalog for Low-Volume Roads: Recommended Minimum PCC Slab Thickness (Inches) for Three Levels of Axle Load Traffic and Five Levels of Roadbed Soil Quality

Inherent reliability: 75 percent.
With Granular Subbase

Load Transfer Devices	**No**				**Yes**			
Edge Support	No		Yes		No		Yes	
S'_c (psi)	600	700	600	700	600	700	600	700
Relative Quality of Roadbed Soil	**Low Traffic**							
Very good & good	5.5	5	5	5	5	5	5	5
Fair	5.75	5.25	5	5	5	5	5	5
Poor & very poor	5.75	5.25	5	5	5	5	5	5
	Medium Traffic							
Very good & good	6.25	5.75	5.75	5.25	6	5.5	5.5	5
Fair	6.5	5.75	6	5.5	6.25	5.5	5.5	5
Poor & very poor	6.5	6	6	5.5	6.25	5.75	5.[illegible]	[illegible]
	High Traffic							
Very good & good	7.25	6.5	6.5	6	6.75	6	6	[illegible]
Fair	7.25	6.5	6.5	6	6.75	6	6	[illegible]
Poor & very poor	7.25	6.75	6.75	6	6.75	6.25	6.[illegible]	[illegible]

Equivalent Sections for a Given Level of Fully Loaded Semi-Tractor Trailers Under Typical Illinois Conditions

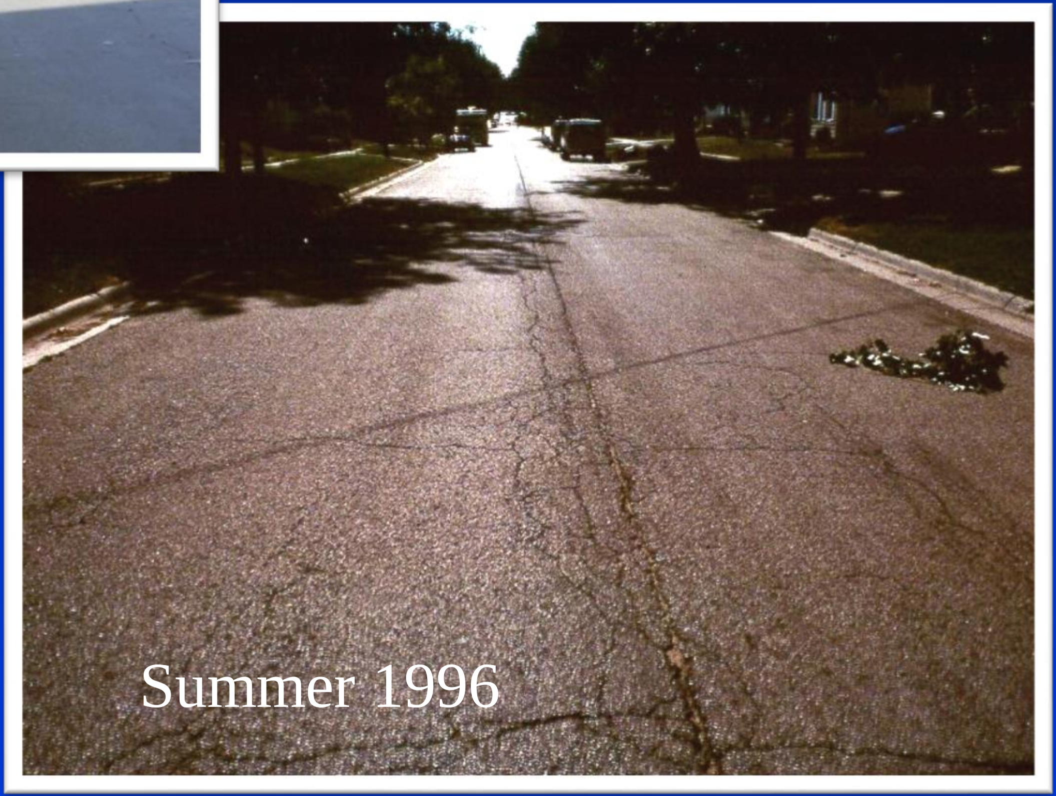
(Based on 1993 AASHTO *Guide for Design of Pavement Structures* - 80 % Reliability)

10 Trucks Per Day

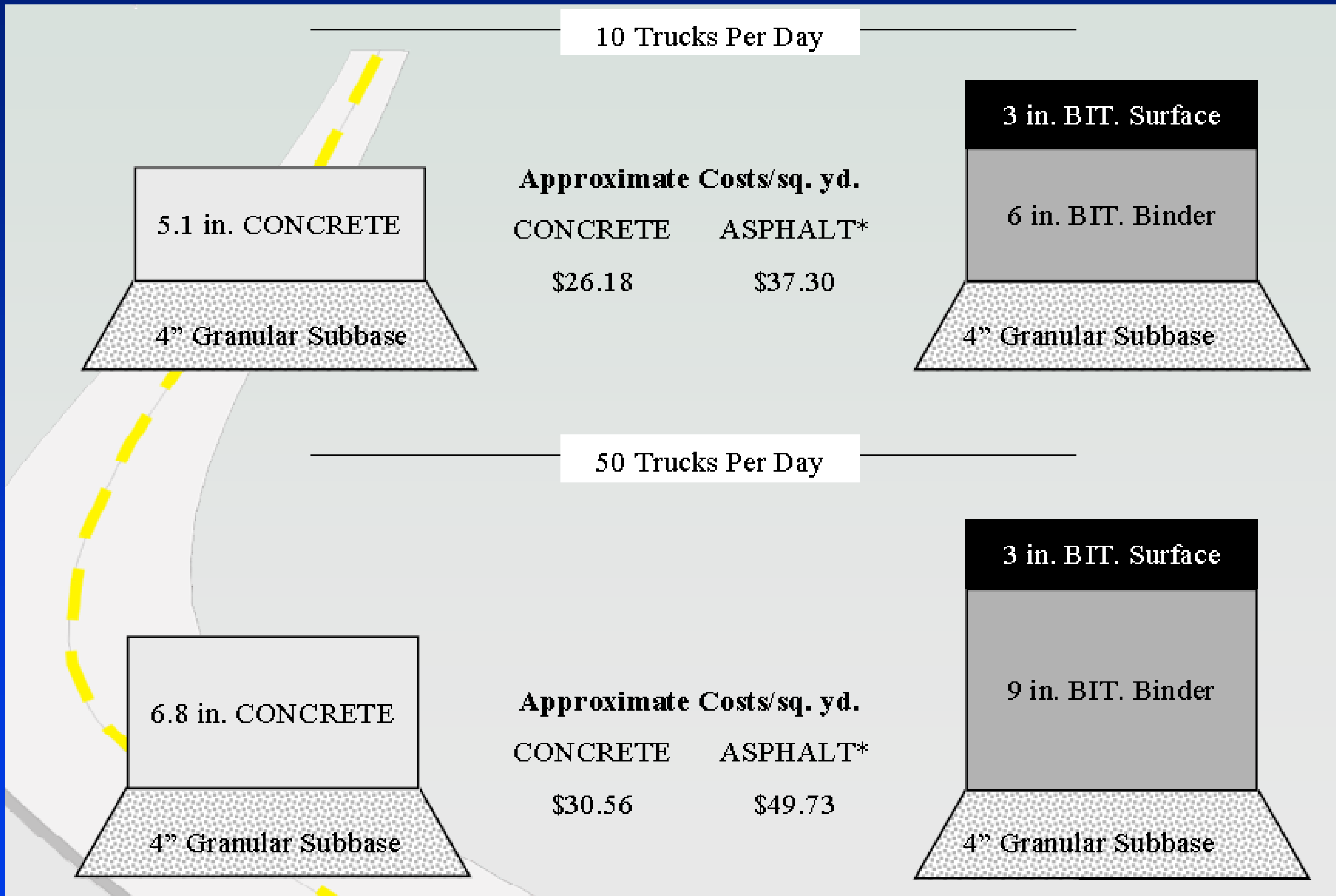
50 Trucks Per Day

Rockford
5” Concrete
Built ’84
About the same time
as the asphalt


January 24, 2013


Summer 1996

Alternates with Approximate Costs



Recommendations for Peoria

- The 7-inch recommendation
  - Conservative for subdivisions
  - Probably light for collectors
  - Should be doweled for anything greater than 85 trucks/day
- Jointing
  - Panel lengths < 15 feet, shorter is better
  - Widths < 13 feet
  - Tied curb and gutter enhances performance
- Granular subbase
  - Test data indicate it is worth about 30 percent increase in performance compared to no subbase
  - But 9 inches is no better than 3 inches
  - Point of diminishing returns reached quickly for concrete

http://www.iowasudas.org/design.cfm

Good Spec. Reference Source

5F-1 Crack Control and Load Transfer

A. General information

A good jointing plan will ease construction by providing clear guidance. The development of a jointing plan requires the designer to think about not only the specific project requirements but also the entire project jointing system. Jointing layouts in some parts of a project can have a substantial impact on other parts. In order to control concrete pavement cracking and subsequently maintain structural integrity, designers need to develop an understanding of how to complete jointing layouts of mainline pavements and intersections to obtain a comprehensive jointing system. This will allow a check on the pattern, type of joints, and the matching joints to their purpose.

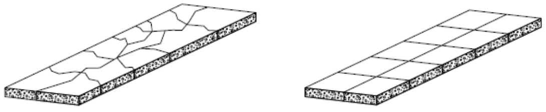
This subsection of the pavement design section deals primarily with plain jointed pavements (tie bars or dowels only at specified joints). The primary function plain jointed pavements is to provide for load transfer across the joint, either through tie bars that hold the adjacent slabs together and allows for aggregate interlock to be maintained; or dowel bars that provide for mechanical load transfer even with slab movement.

Some cities in Iowa utilize jointed reinforced (JR) pavements, sometimes referred to as distributed steel reinforcing pavements. Section 5F-2, F discusses joint reinforced pavements. Joint reinforced pavements are used primarily to control cracking of a concrete pavement, to provide for load transfer, and to maintain the structural integrity of the slab between transverse joints. Joint reinforced pavements should not be confused with continuously reinforced pavement, which has very few or no joints.

The primary benefits of jointing are as follows:

1. **Crack control.** Cracking results from stress caused by concrete drying shrinkage, subgrade restraint, temperature/moisture differentials and applied traffic loads, and the combined effects of restraint curling and warping. It is highly desirable to control the location and geometry of transverse and longitudinal cracking in pavements. Without this control, cracking occurs in a random pattern similar to Figure 1, which results in increased distress of the joints.

Figure 1: Effect of sawing on crack control.



Random Cracking without Sawing   Controlled Cracking with Sawing

2. Accommodating slab movements.
3. Providing desirable load transfer.

Other Benefits of Concrete

- Durable rut resistant surface
- Reduce interim maintenance
- Environmentally Friendly
  - Light Reflective - Day and Night
  - Reduces Urban Heat Island Effects
- In today's environment, it may even cost less!

Thanks for your time!

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